

F, as illustrated in Figure 16. Therefore, the acceptable crosstalk levels determine the minimum waveguide pitch  $p_{\min}$ .

According to the present invention, and as shown in Figure 15B, a longitudinal gap can be used to prevent the excitation and subsequent propagation of the higher order even mode, which has a transverse current maximum in the top and bottom ground plane structures at  $x = 0$ . Figure 15B depicts an NRD waveguide backplane system 120 of the present invention. Waveguide backplane system 120 includes an upper conductive plate 124U, and a lower conductive plate 124L disposed opposite and generally parallel to upper plate 124U. Preferably, plates 124U and 124L are made from a suitable conducting material, such as a copper alloy, and are grounded.

A dielectric channel 122 is disposed along a waveguide axis 130 between conductive plates 124U and 124L. Gaps 128 in the conductive plates are formed along waveguide axis 130. Preferably, gaps 128 are disposed near the middle of each dielectric channel 122. An air-filled channel 126 is disposed along waveguide axis 130 adjacent to dielectric channel 122. In a preferred embodiment, waveguide 120 can include a plurality of dielectric channels 122 separated by air-filled channels 126. Dielectric channels 122 could be made from any suitable material.

The bandwidth of the TE  $1,0$  mode NRD waveguide is dependent on the losses in dielectric and the conducting ground planes. For the case where  $b \sim a/2$ , and the approximation to the eigenvalue

$$k \sim (\omega/c)(Dr - 1)^{0.5} \sim 2/a, \quad (11)$$

holds. The attenuation has two components: a linear term in frequency proportional to the dielectric loss tangent, and a  $3/2$  power term in frequency due to losses in the conducting ground planes. For an attenuation of this form

$$\alpha = (\alpha_1)(f)^{1.5} + (\alpha_2)f \quad (12)$$

where  $\alpha_1$  and  $\alpha_2$  are constants. The bandwidth-length product,  $BW \cdot L$ , based on the upper

side-band 3 dB point is

$$BW \cdot L \sim (0.345/a_2) / (1/2)(a_1/a_2)(f_0)^{0.5} + 1 \quad (13)$$

where  $BW/f_0 < 1$ , and  $f_0$  is the nominal carrier frequency. Preferably, pitch  $p$  is a multiple of width  $a$ . Then, from (3),  $f_0$  is proportional to  $1/p$ . Also, bandwidth density  $BWD =$

- 5  $BW/p$ . Plots of the bandwidth and bandwidth density characteristics for a "TEFLON" NRD waveguide, and for a Quartz NRD guide having  $Dr = 4$  and a loss tangent of 0.0001 are shown in Figure 9. For these plots  $p = 3a$ . Thus, like the characteristics of rectangular waveguide 100, NRD waveguide 120 offers increased bandwidth and, more importantly, an open ended bandwidth density characteristic relative to the parabolically closed
- 10 bandwidth performance of conventional PCB backplanes.

- Thus, there have been disclosed broadband microwave modem waveguide backplane systems for laminated printed circuit boards. Those skilled in the art will appreciate that numerous changes and modifications may be made to the preferred embodiments of the invention and that such changes and modifications may be made
- 15 without departing from the spirit of the invention. For example, Figure 9 also includes a reference point for a minimum performance, multi-mode fiber optic system which marks the lower boundary of fiber optic systems potential bandwidth performance. It is anticipated that the microwave modem waveguides of the present invention can provide a bridge in bandwidth performance between conventional PCB backplanes and future fiber
- 20 optic backplane systems. It is therefore intended that the appended claims cover all such equivalent variations as fall within the true spirit and scope of the invention.

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